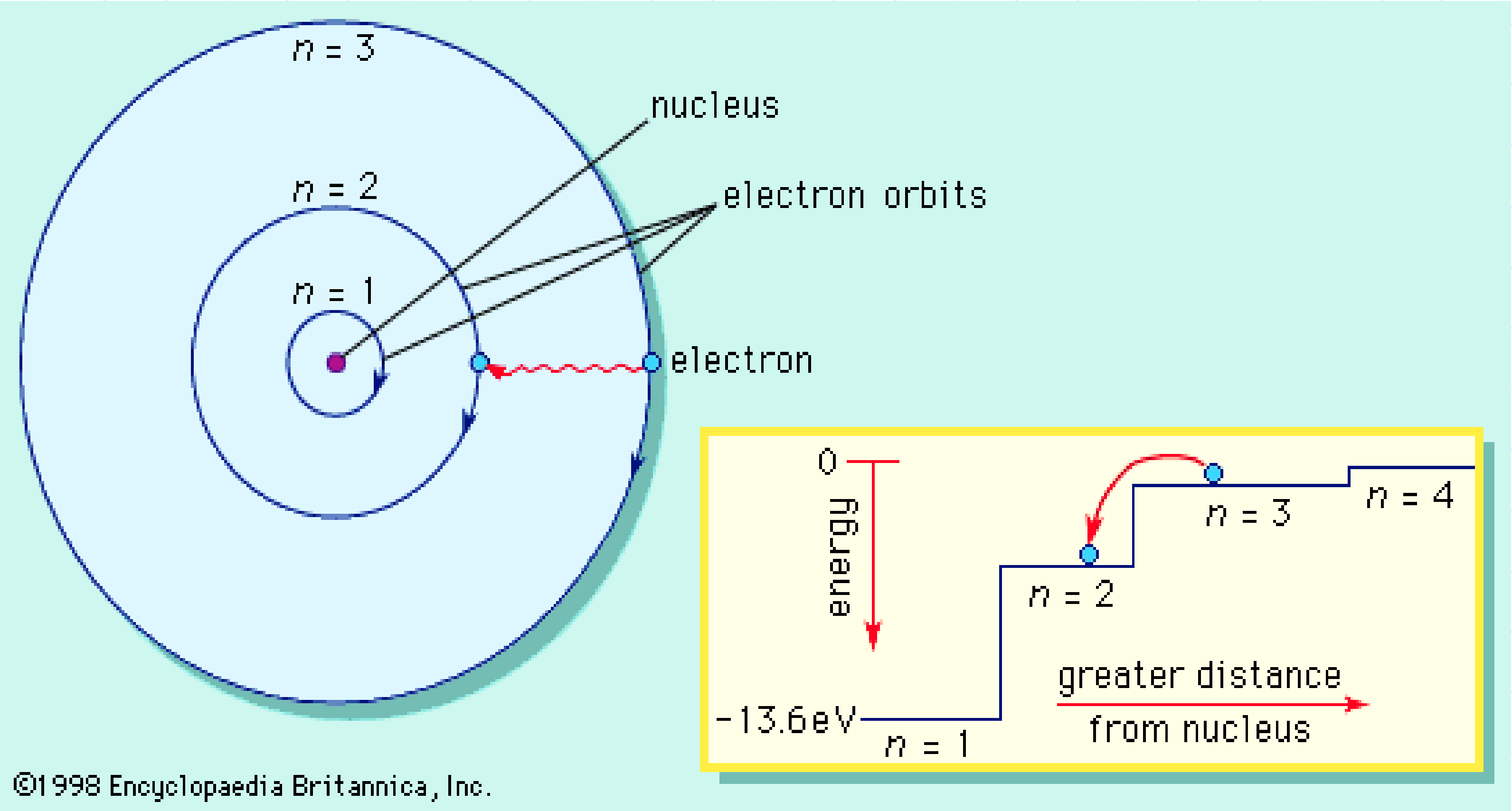
IB Chemistry

ATOMIC THEORY

Adapted from Scheffler
Lincoln HS, Portland OR

Focus on Bohr's Model:



Energy Levels

- Electrons go in shells or energy levels. The energy levels are called **principle energy levels**, 1 to 4.
- The energy levels contain sub-levels.

Principle energy level	Number of sub-levels
1	1
2	2
3	3
4	4

These sub-levels are assigned the letters, s, p, d, f

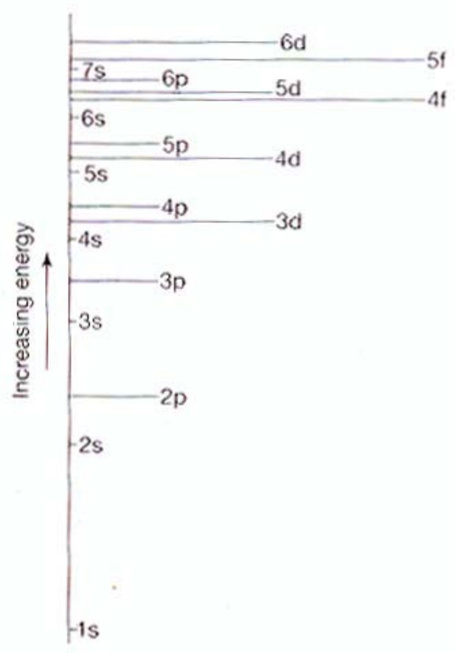
Energy Levels

- Each type of sub-level can hold a different maximum number of electron.

Sub-level	Maximum number of electrons
s	2
p	6
d	10
f	14

Energy Levels

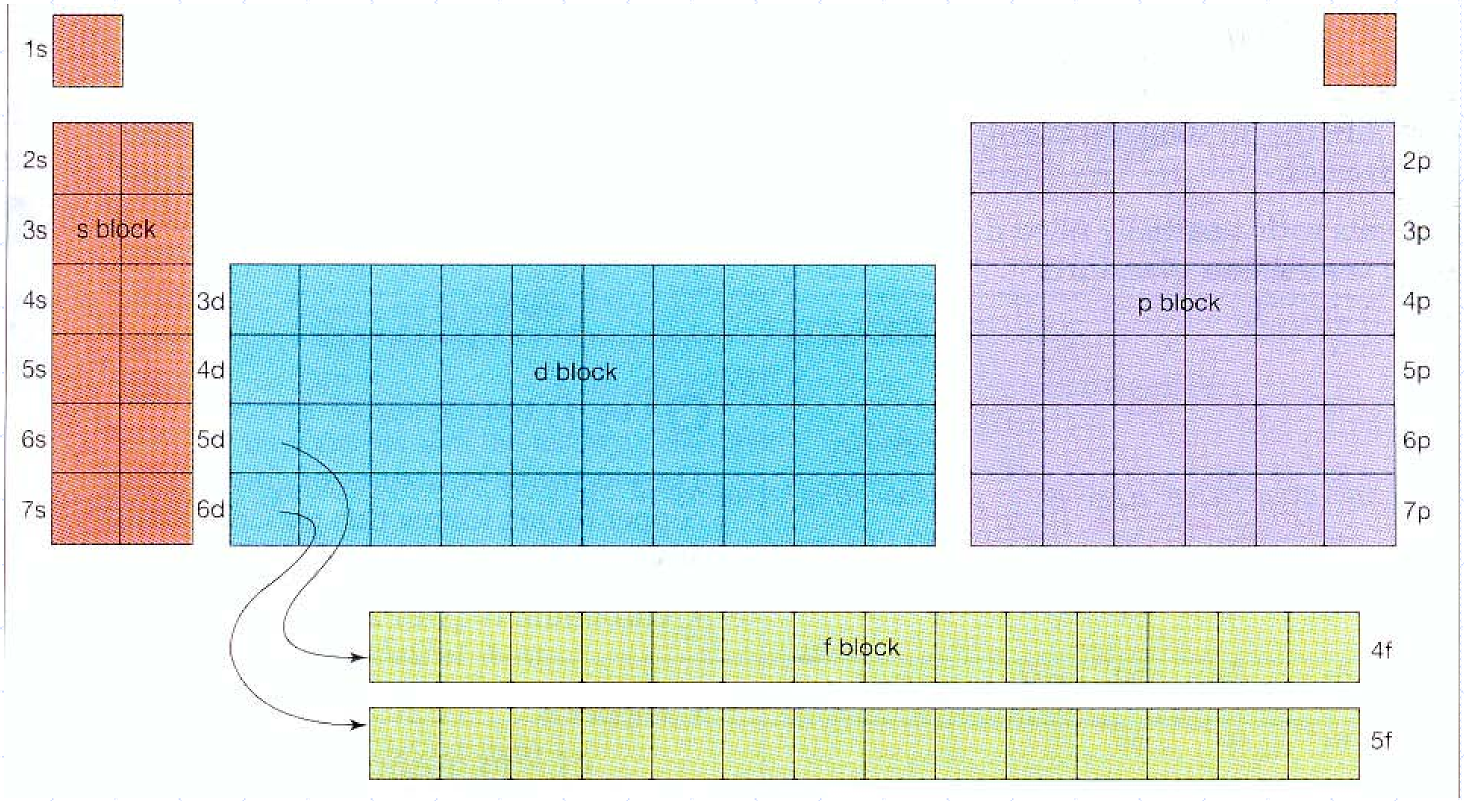
- The energy of the sub-levels increases from s to p to d to f. The electrons fill up the lower energy sub-levels first.



Looking at this table can you work out in what order the electrons fill the sub-levels?

Energy Levels

- Let's take a look at the Periodic Table to see how this fits in.



Electronic Structure

- So how do you write it?

$1s^2$

Energy level

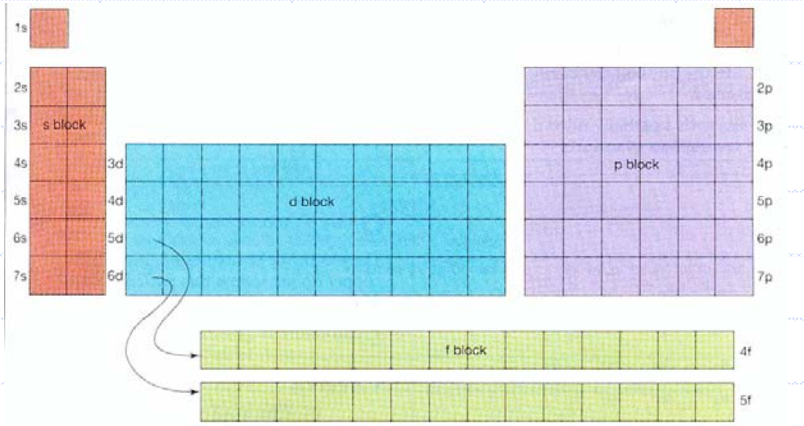
Sub-level

Number of electrons

Example

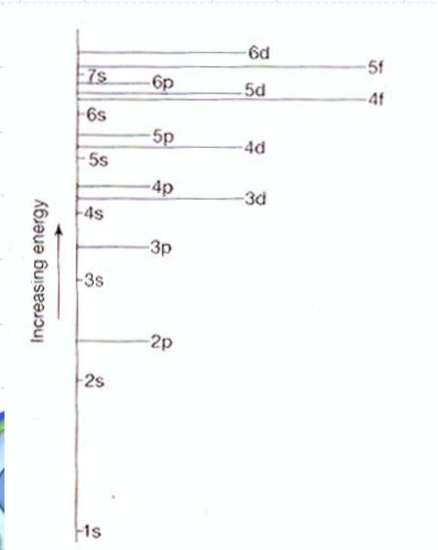
For magnesium:

$1s^2, 2s^2, 2p^6, 3s^2$

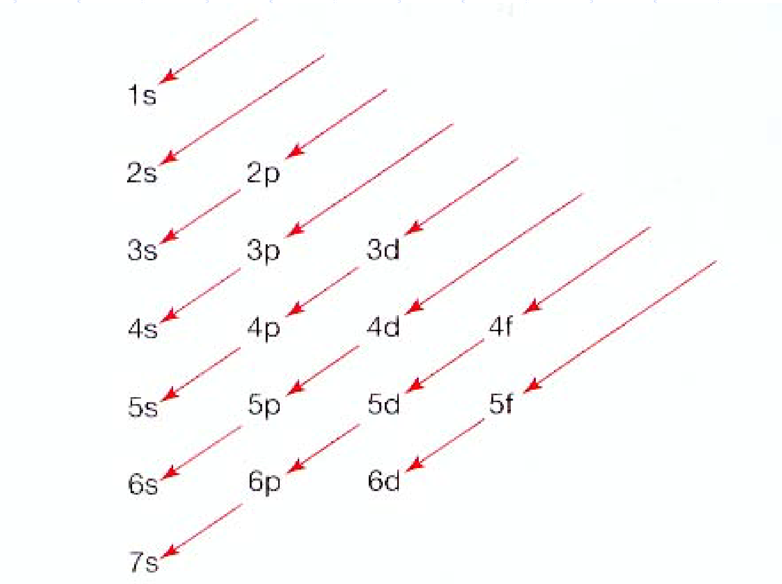


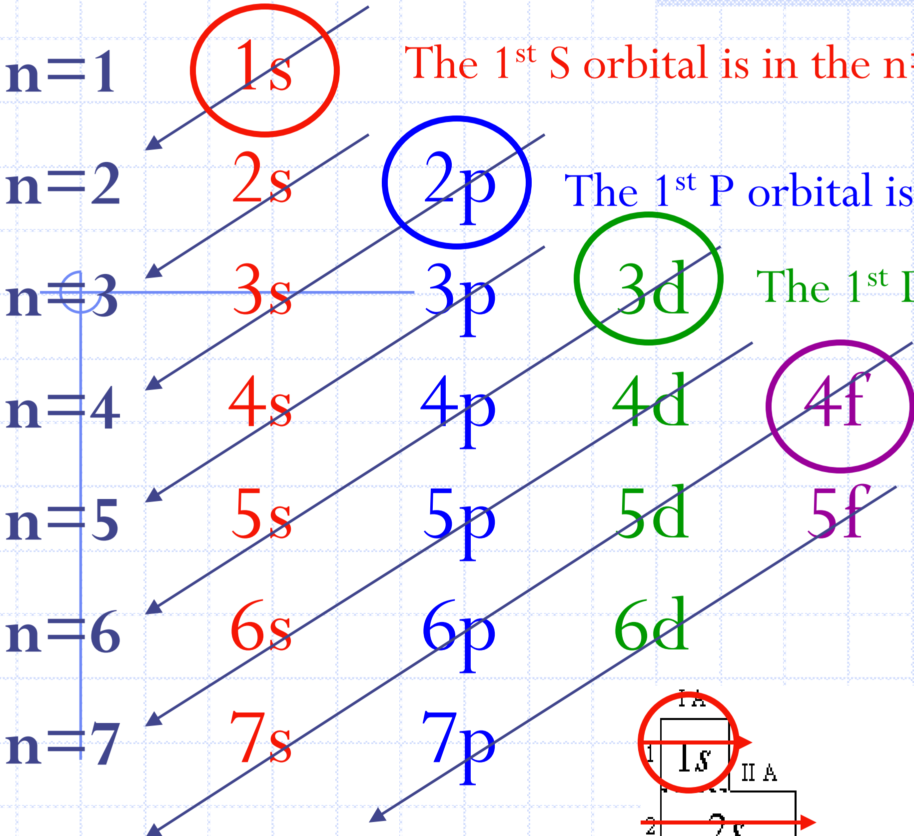
Electronic Structure

- The electronic structure follows a pattern – the order of filling the sub-levels is 1s, 2s, 2p, 3s, 3p...
- After this there is a break in the pattern, as that the 4s fills before 3d.
- Taking a look at the table below can you work out why this is?



- This is because the 4s sub-level is of lower energy than the 3d sub-level.





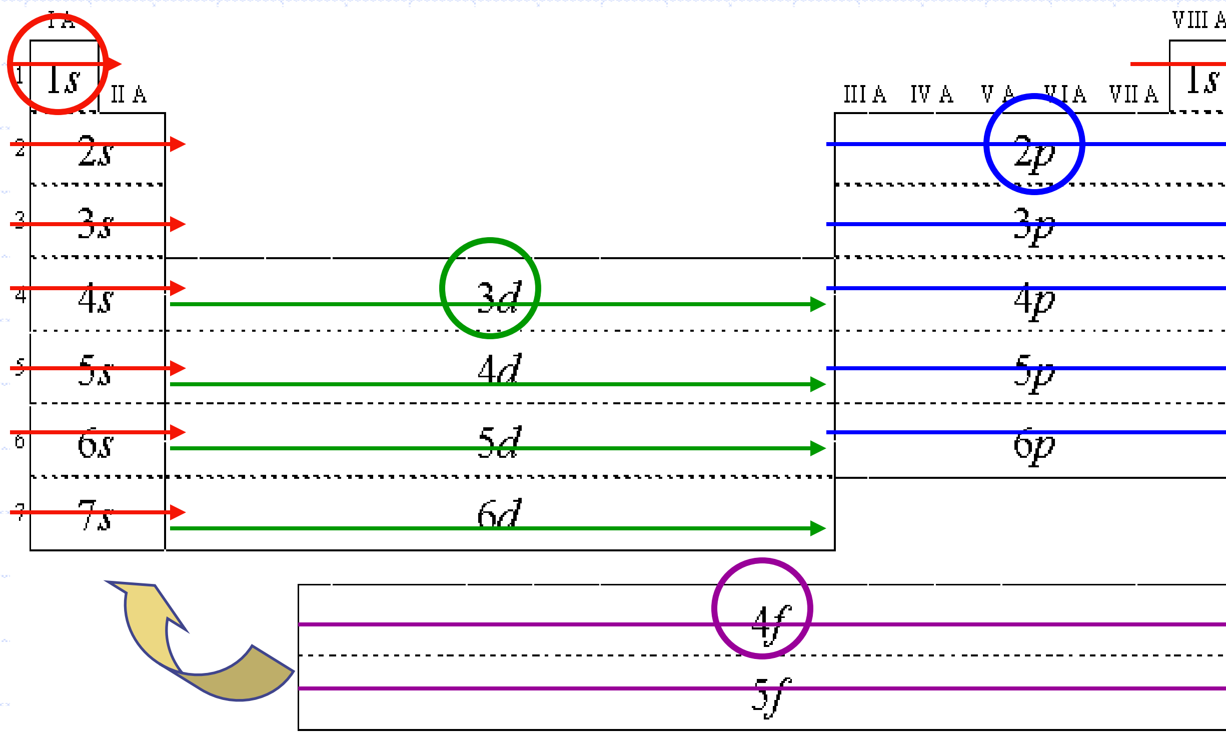
The 1st S orbital is in the n=1 energy level

The 1st P orbital is in the n=2 energy level

The 1st D orbital is in the n=3 energy level

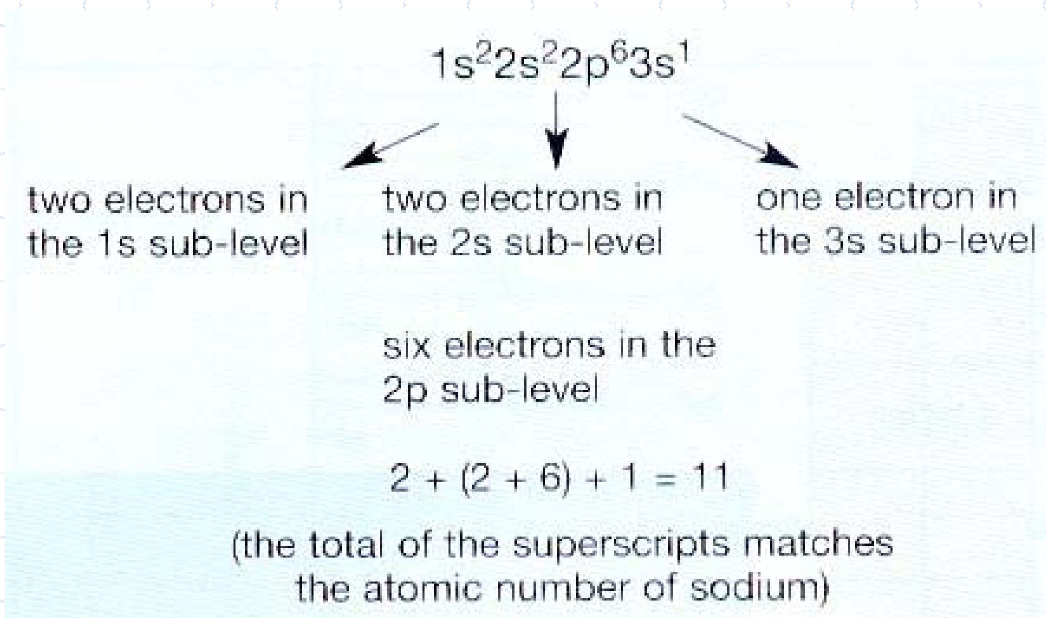
The 1st F orbital is in the n=4 energy level

Filling Order of Orbitals (link)



Electronic Structure

- The order in this the energy levels are filled is called the Aufbau Principle.
- Example (Sodium – 2, 8, 1)



Electronic Structure

- There are two exceptions to the Aufbau principle.
- The electronic structures of chromium and copper do not follow the pattern – they are anomalous.
- Chromium – $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^5$, $4s^1$
- Copper – $1s^2$, $2s^2$, $2p^6$, $3s^2$. $3p^6$, $3d^{10}$, $4s^1$

Write the electronic configuration for the following elements:

a) hydrogen	c) oxygen	e) copper
b) carbon	d) aluminium	f) fluorine

Electronic Structure – of ions

- When an atom loses or gains electrons to form an ion, the electronic structure changes:
  - Positive ions: formed by the loss of e^-

$$1s^2\ 2s^2\ 2p^6\ 3s^1 \rightarrow 1s^2\ 2s^2\ 2p^6$$

Na atom **Na^+ ion**

  - Negative ions: formed by the gain of e^-

$$1s^2\ 2s^2\ 2p^4 \rightarrow 1s^2\ 2s^2\ 2p^5$$

O atom **O^- ion**

Electronic Structure – of transition metals

- With the transition metals it is the **4s** electrons that are lost first when they form ions:
  - Titanium (Ti) - loss of 2 e^-

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ \mathbf{4s^2} \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$

Ti atom **Ti^{2+} ion**

  - Chromium (Cr) - loss of 3 e^-

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ \mathbf{4s^1} \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

Cr atom **Cr^{3+} ion**

Electronic Structure - **Questions**

- Give the full electronic structure of the following positve ions:

  a) Mg^{2+} b) Ca^{2+} c) Al^{3+}

- Give the full electronic structure of the negative ions:

  a) Cl^{-} b) Br^{-} c) P^{3-}

Electronic Structure - Questions

- Copy and complete the following table:

	Atomic no.	Mass no.	No. of protons	No. of neutrons	No. of electrons	Electronic structure
Mg				12		$1s^2\ 2s^2\ 2p^6\ 3s^2$
Al^{3+}		27			10	
S^{2-}			16	16		
Sc^{3+}	21	45				
Ni^{2+}				30	26	

Orbitals

- The energy sub levels are made up of orbitals, each which can hold a maximum of 2 electrons.
- Different sub-levels have different number of orbitals:

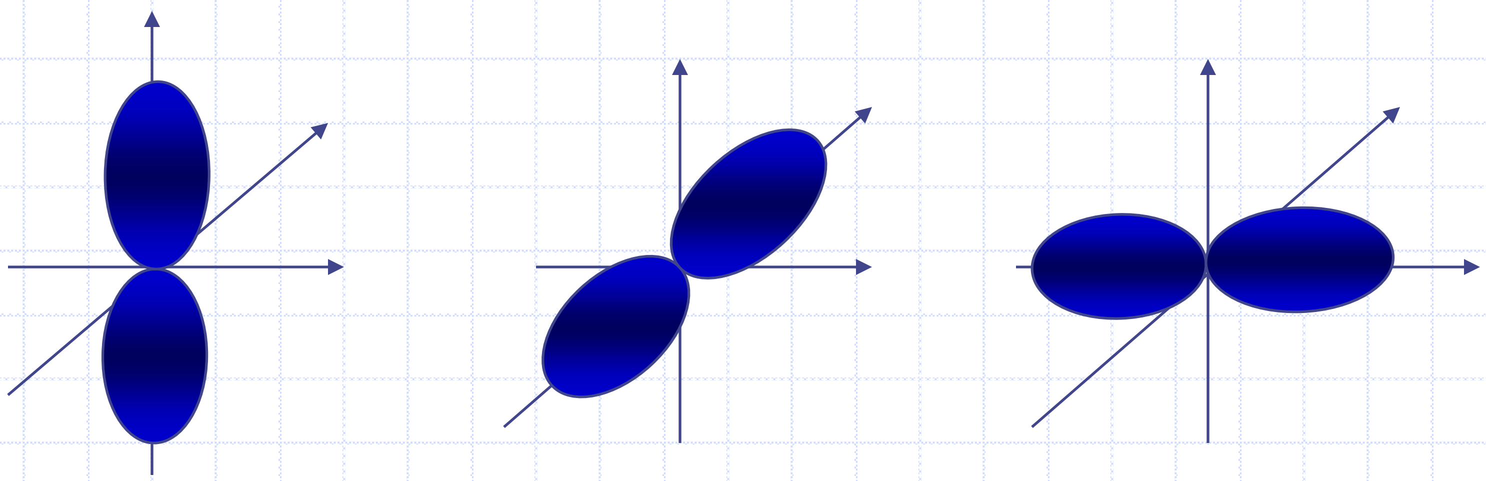
Sub-level	No. of orbitals	Max. no. of electrons
s	1	2
p	3	6
d	5	10
f	7	14

Orbitals

- The orbitals in different sub-levels have different shapes:
  - **s orbitals**

1s 2s

  - **p orbitals**

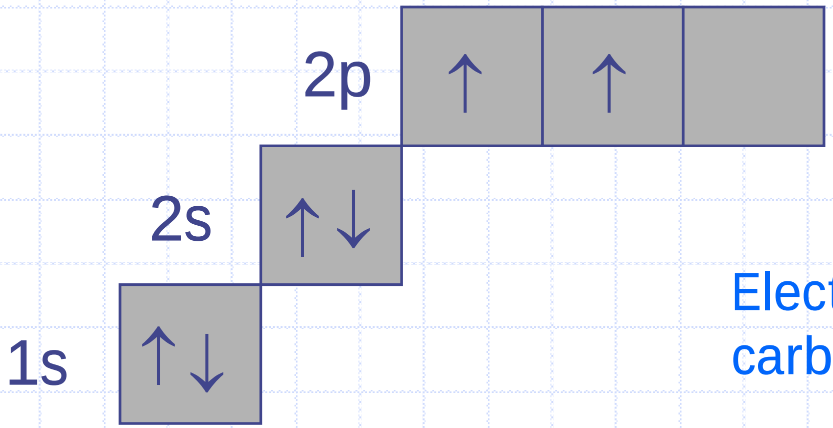


What do d, f, g, h look like?

- Remember, these orbitals represent mathematical calculations of where electrons (behaving wave-like) reside. The calculation is a probability. As the equation calculates probability further from the nucleus the equations and space-filling representations become very…… funky.
- Probability Clouds

Orbitals

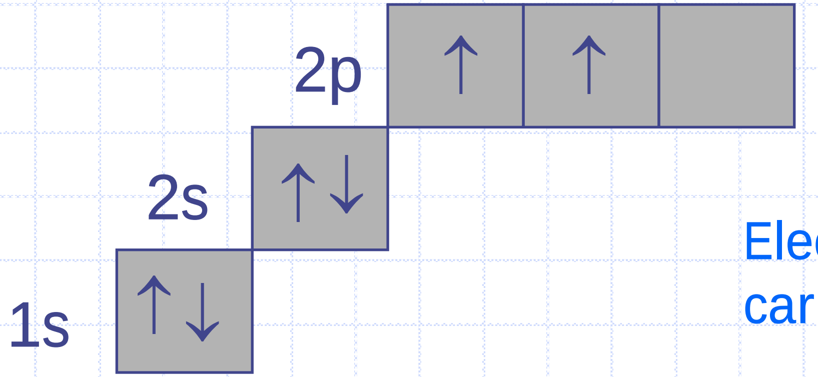
- Within a sub-level, the electrons occupy orbitals as unpaired electrons rather than paired electrons. (This is known as **Hund's Rule**).
- We use boxes to represent orbitals:



Electronic structure of carbon, $1s^2$, $2s^2$, $2p^2$

Orbitals

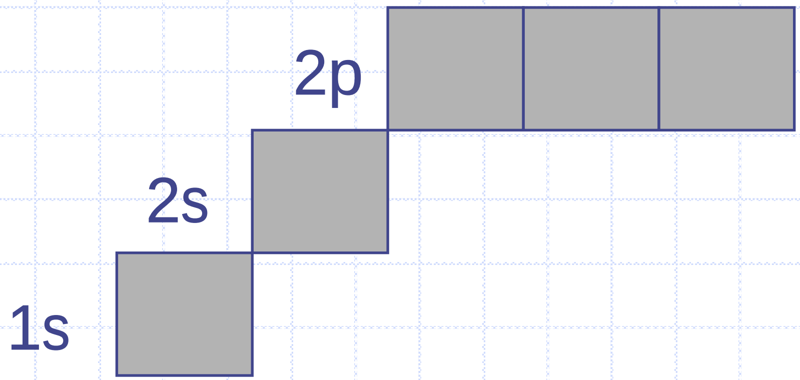
- The arrows represent the electrons in the orbitals.
- The direction of arrows indiactes the spin of the electron.
- Paired electrons will have opposite spin, as this reduces the **mutual repulsion** between the paired electrons.



Electronic structure of carbon, $1s^2$, $2s^2$, $2p^2$

Orbitals

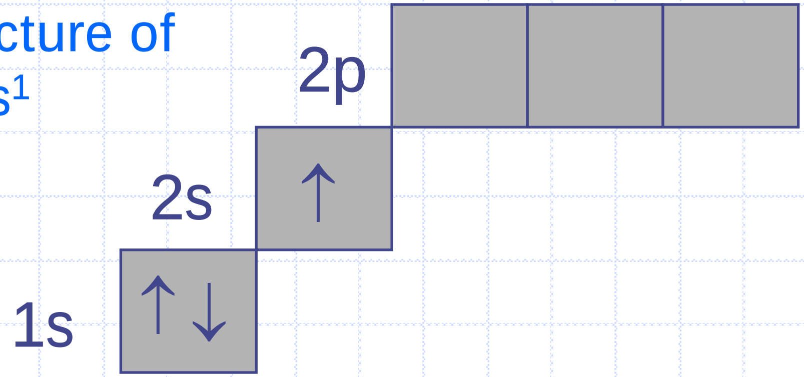
- Using boxes to represent orbitals, give the full electronic structure of the following atoms:
  - a) lithium
  - b) fluorine
  - c) potassium
  - d) nitrogen
  - e) oxygen



Orbitals

- Using boxes to represent orbitals, give the full electronic structure of the following atoms:
  - a) lithium
  - b) fluorine
  - c) potassium
  - d) nitrogen
  - e) oxygen

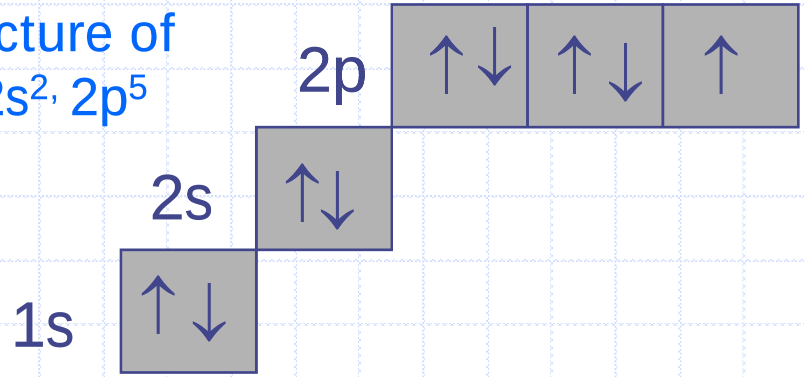
Electronic structure of lithium: $1s^2$, $2s^1$



Orbitals

- Using boxes to represent orbitals, give the full electronic structure of the following atoms:
  - a) lithium
  - b) fluorine
  - c) potassium
  - d) nitrogen
  - e) oxygen

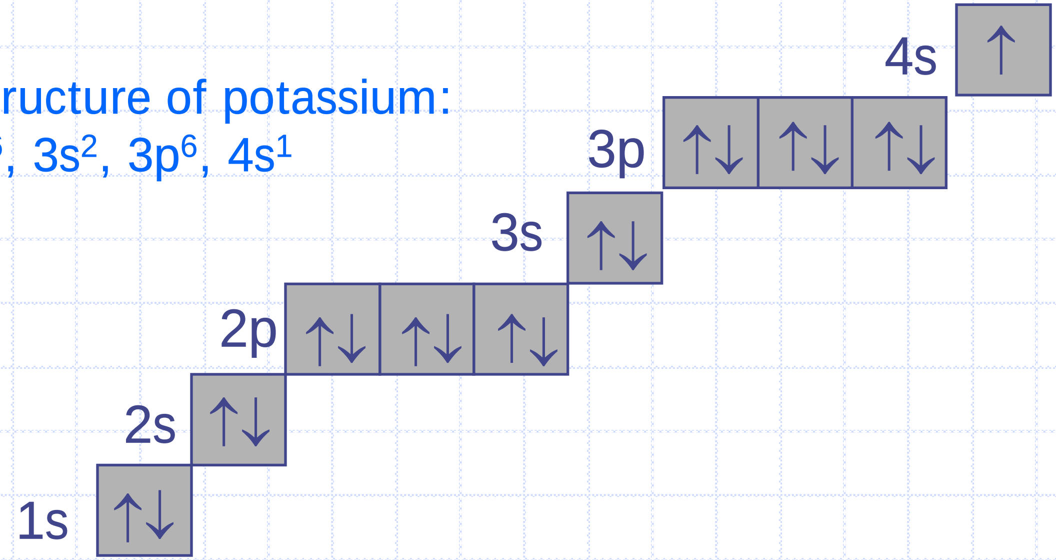
Electronic structure of fluorine: $1s^2$, $2s^2$, $2p^5$



Orbitals

- Using boxes to represent orbitals, give the full electronic structure of the following atoms:
  - a) lithium
  - b) fluorine
  - c) potassium
  - d) nitrogen
  - e) oxygen

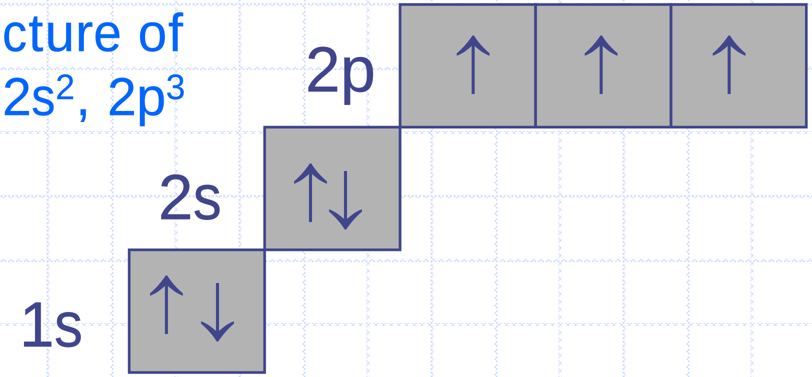
Electronic structure of potassium:
$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^1$



Orbitals

- Using boxes to represent orbitals, give the full electronic structure of the following atoms:
  - a) lithium
  - b) fluorine
  - c) potassium
  - d) nitrogen
  - e) oxygen

Electronic structure of nitrogen: $1s^2$, $2s^2$, $2p^3$



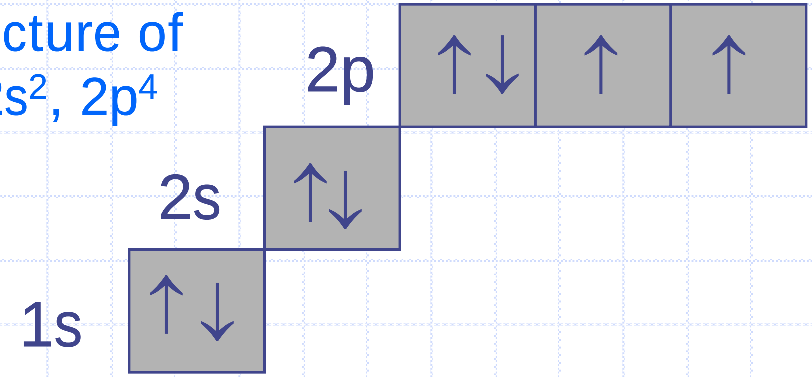
Orbitals

- Using boxes to represent orbitals, give the full electronic structure of the following atoms:

  a) lithium   b) fluorine   c) potassium

  d) nitrogen   e) oxygen

Electronic structure of oxygen: $1s^2$, $2s^2$, $2p^4$



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